

Biological Affinities and Adaptations of Bronze Age Bactrians: III. An Initial Craniometric Assessment

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Indus Valley

ABSTRACT Discovery of a previously unknown Bronze Age civilization (Oxus Civilization) centered on the oases of Central Asia immediately raised questions concerning the origin and interregional impacts of this civilization. Fifteen craniometric variables from 12 Bronze Age samples—encompassing 544 adults from Central Asia, Iran, the Indus Valley, and Anatolia—are compared to test which, if any, of the current hypotheses offered by archaeologists are best supported by the pattern of phenetic affinities possessed by the Oxus Civilization inhabitants of the north Bactrian oasis. Craniometric differences between samples are compared with Mahalanobis generalized distance, and patterns of phenetic affinity are assessed with two types of cluster analysis (WPGMA, neighbor-joining method), multidimensional scaling, and principal coordinates analysis. Results obtained by this analysis indicate that current hypotheses for both the origin and interregional impacts of Oxus Civilization populations are incomplete. *Am J Phys Anthropol* 106:329–348, 1998. © 1998 Wiley-Liss, Inc.

Mysterious Bronze Age artifacts have been sold on the black market in Kabul for decades. These objects, although exhibiting some iconographic similarities to the known traditions of Iran to the west and the Indus Valley to the east, seemed to reflect a separate and unique cultural tradition (Sarianidi, 1981, 1985, 1987, 1994; Amiet, 1986). No one knew the point of origin of these unusual artifacts, yet with continued excavations, these objects began to appear as isolated elements in numerous Bronze Age assemblages from Iran and Pakistan. During the 1960s and 1970s, a series of excavations by Soviet archaeologists revealed the existence of a previously unknown Bronze Age civilization in southern Central Asia (Masson and Sarianidi, 1972; Askarov, 1977, 1981; Sarianidi, 1977, 1981; Masson, 1981a). There, urban centers were found that contained artifact assemblages dominated by these previously mysterious objects. These

urban centers are concentrated in the foothill plain along the northern slopes of the Kopet Dagh foothills of south-central Turkmenistan (Altyn depe, Namazga, Kara depe), the Margiana oasis of eastern Turkmenistan (Togolok, Gonur depe), and the northern, southern, and eastern Bactrian oases of southern Uzbekistan and northern Afghanistan (Sapalli tepe, Djarkutan).

The recent discovery of this civilization, variously labeled as the Namazga Civilization (Kohl, 1981), the Bactrian Civilization (Askarov, 1977; Sarianidi, 1977; Tosi, 1988; Ligabue and Salvatori, 1988), and the Oxus Civilization (Francfort, 1989; Hiebert, 1994; Lamberg-Karlovsky, 1994a,b), immediately

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raised several important issues. Where did this civilization come from? What impact did this civilization have on neighboring Bronze Age urban centers in Iran and the Indus Valley? This article addresses these questions by comparing craniometric variation within the population of the Oxus Civilization, and between this group and others, as detailed in the historical summaries below.

Origins of the Oxus Civilization

Archaeologists are divided over the most likely origin of Oxus Civilization populations. The predominant hypothesis holds that the oases of Margiana and Bactria were unoccupied before the Initial Late Bronze Age (before *c.* 2200 B.C.; Kohl, 1992). With the development of sophisticated irrigation technology in the Kopet Dagh foothill plain of south-central Turkmenistan during the Middle Bronze Age (*c.* 2500–2000 B.C.; Kohl, 1992), subsequent population pressure led to wholesale colonization eastward into the previously unoccupied oases of Margiana and Bactria.

Proponents of this hypothesis maintain that the close similarity of earlier ceramic wares from the urban centers of south-central Turkmenistan with those from northern Iranian sites indicate an initial north-eastward movement of peoples from northern Iran to the Kopet Dagh foothill plain during the fourth millennium B.C. (Masson and Sarianidi, 1972). Later ceramic wares from this region appear to be derived from this earlier tradition and are maintained to be the best prototypes for the characteristic artifact assemblages of the Oxus Civilization (designated as the Bactrian-Margiana Archaeological Complex [BMAC]; Hiebert, 1994) found in the urban centers of Bactria and Margiana. By asserting that these ceramics represent the direct antecedent of the BMAC, proponents of this hypothesis maintain that the Oxus Civilization populations of Bactria and Margiana are the product of wholesale colonization from the urban centers of south-central Turkmenistan (Masson and Sarianidi, 1972; Askarov, 1974, 1977, 1981, 1988; Biscione, 1977; Masimov, 1979; Masson, 1981a, 1989, 1992a,b; Hiebert and Lamberg-Karlovsky, 1992; Lamberg-Karlovsky, 1994b).

An alternative view has been offered by Udemuradov (1988). Although agreeing that artifactual evidence indicates a close tie between the oases of Bactria and Margiana with the Kopet Dagh foothill zone, Udemuradov maintains that the interaction between these regions was not one of wholesale colonization into unoccupied oases. Rather, a small but significant population resided within these oases before the appearance of the Oxus Civilization. Udemuradov suggests that the impact of Kopet Dagh populations on the resident populations of Bactria, and by extension, Margiana, was one of ever-increasing gene flow from west to east, rather than a wholesale transplantation of Kopet Dagh populations.

Discovery of the Harappan outpost of Shortughai in the eastern Bactrian oasis of northern Afghanistan (Francfort, 1984, 1989), along with the discovery of a few artifacts at Altyn depe attributed to the Indus Civilization (Masson, 1981a,b,c, 1989, 1992a), has stimulated a third hypothesis for the origin of the Oxus Civilization. This alternative holds that Oxus Civilization populations of Bactria, and perhaps Margiana, may derive from the southeast—from populations of the Indus Valley of Pakistan rather than from populations of the Kopet Dagh foothill plain to the west.

Interregional influences of the Oxus Civilization

Models of the impact of Oxus Civilization populations on neighboring urban Bronze Age populations are as contentious as theories concerning their origin. The dominant view asserts that the oases of Margiana and Bactria represent the center of a new and vigorous commercial power that spread throughout the Indo-Iranian borderlands toward the end of the mature-Harappan period, around 2000 B.C. (Hiebert and Lamberg-Karlovsky, 1992; Lamberg-Karlovsky, 1993, 1994b; Sarianidi, 1993, 1994; Hiebert, 1994, 1995). In fact, the presence of characteristic Oxus Civilization artifacts in Pakistani Baluchistan led Hiebert and Meadow (1991) to assert that this Central Asian civilization represented a strong presence on the edge of the Indus Valley—a presence that certainly affected the Indus Civilization

near the end of the mature-phase (for another view see Jarrige, 1997).

This theme has been taken up by Parpola (1988), who noted that the spread of characteristic Oxus Civilization artifacts from Central Asia throughout the Indo-Iranian borderlands involves not just a few isolated objects, but an entire complex of material cultural items. Parpola asserts that the rapid, unidirectional transplantation of this archaeological complex may signal an actual physical movement of Oxus Civilization "conquerors," who replaced indigenous populations in eastern Iran and the periphery of the Indus Valley during the immediate post-Harappan period.

A less dramatic, but similarly unidirectional view of the interregional effects of Oxus Civilization populations has been offered by Hiebert (1994) and Lamberg-Karlovsky (1993, 1994b). These scholars interpret the appearance of an entire complex of characteristic Central Asian artifacts throughout the vast Indo-Iranian borderlands as evidence that the Oxus Civilization established "colonies" in the urban centers of neighboring Bronze Age cultures. These researchers speculate that once settled in these distant regions, Oxus colonists may have served important economic or political roles, linking these distant colonies to the urban centers of Bactria and Margiana.

A different interpretation of the interregional effects of Oxus Civilization populations has been offered by Jarrige (1994). Jarrige claims that throughout the first half of the second millennium B.C., the Indo-Iranian borderlands witnessed a general semihomogenization of local cultures. Site assemblages throughout this region are marked by unique combinations of general Indo-Iranian influences with items that indicate a continuance of locally distinctive traditions. Jarrige interprets these data as indicative of the participation of local elite groups, who shared a common socioreligious orientation and iconography, in a bidirectional exchange network with other elites throughout this vast region. The product of this ever-increasing bidirectional exchange was the formation of a *koiné*, or sphere of interaction in which no single region held hegemonistic power over the others (see also

Amiet, 1988; Tosi, 1988). Although Jarrige's analysis is restricted to assessment of ceramic wares and decorative motifs, such a *koiné* may have involved the bidirectional exchange of individuals (genes) and commodities.

Although it would be foolish to directly equate the movement and homogenization of artifacts with that of populations, it is nevertheless true that options for interregional interaction (and even more specifically, marital alliances) most often occur along established trade routes (Lamberg-Karlovsky and Tosi, 1973; Anthony, 1990). Indeed, such movements are well known from demographic studies, in which incremental genetic exchange between a whole series of intermediate localities is known as "channelized" or "chain" migration (MacDonald and MacDonald, 1964; Hillery and Brown, 1965; Alvarez, 1987). Because of these factors, Jarrige's interpretation of trade and exchange across the Indo-Iranian borderlands stands in marked contrast, both in directionality and intensity, to the unidirectional exportation of Oxus Civilization commodities (Hiebert and Lamberg-Karlovsky, 1992; Hiebert, 1994; Lamberg-Karlovsky, 1994b) and even populations (Parpola, 1988; Lamberg-Karlovsky, 1993; Hiebert, 1994).

Aim of this study

This article compares craniometric variation among Oxus Civilization inhabitants of the north Bactrian oasis of southern Uzbekistan with Bronze Age samples from Iran and the Indus Valley. The results of this comparison are used to test which, if any, of the alternative hypotheses advanced by archaeologists best explain the origins and interregional effects of Oxus Civilization populations.

Measurements of the neurocranium and facial skeleton have been used for many years to provide an assessment of the degree of biological relatedness among samples of past and living populations. Although it is clear that these measurements actually provide assessment of an unknown combination of environmental and hereditary factors (Cavalli-Sforza and Bodmer, 1971) and may be affected by masticatory mechanics (Carlson and Van Gerven, 1977; Van Gerven,

TABLE 1. *Samples considered in the study*

Code ¹	Maximum sample size		Site/region	Period	Dates	Reference
	Males	Females				
CEMH	13	18	Harappa/Indus Valley	Late Harappan	1900–1600B.C.	Gupta et al. (1962)
DJR	16	32	Djarkutan/North Bactria	Djarkutan phase	2000–1800B.C.	This Report
HAR	23	41	Harappa/Indus Valley	Mature Harappan	2500–2000B.C.	Gupta et al. (1962)
KUZ	12	9	Djarkutan/North Bactria	Kuzali phase	1800–1650B.C.	Hemphill et al. (1991) This Report
MHD	10	6	Mohenjo-daro/Indus Valley	Mature Harappan?	2500–2000B.C.	Sewell and Guha (1931) Guha and Basu (1938)
MOL	18	26	Djarkutan/North Bactria	Molali phase	1650–1500B.C.	This Report
SAP	13	26	Sapalli tepe/North Bactria	Sapalli phase	2200–2000B.C.	This Report
SHS	45	43	Shahr-i Sokhta/Eastern Iran	SHS I, II, III	3000–2200B.C.	Pardini and Sarvari-Negahban (1976) Pardini (1977, 1979–1980)
TAJ	10	9	Tell al-Judiadah/Anatolia	Neolithic/Iron Age	5000–64 B.C.	Krogman (1949)
TH2	9	7	Tepe Hissar/North-west Iran	Tepe Hissar II	3500–3000B.C.	Krogman (1940)
TH3	102	36	Tepe Hissar/North-west Iran	Tepe Hissar III	3000–1750B.C.	Krogman (1940)
TMG	9	11	Timargarha/Indus Valley	Late Bronze/Early Iron	1400–800 B.C.	Bernhard (1967)

¹ Abbreviations for samples are defined in the text.

1982) and environmental variation (Beals, 1972; Guglielmino-Matessi et al., 1979), twin studies (Lundstrom, 1954; Clark, 1956; Nakata et al., 1974a; Orczykowska-Swiatkowska and Lebiada, 1975; Saunders et al., 1980), familial studies (Howells, 1966; Nakata et al., 1974b; Susanne, 1975, 1977; Devor, 1987), and world-wide comparisons of craniometric variation reveal a moderate degree of genetic control ($0.52 < h^2 < 0.72$; Susanne, 1975, 1977) and demonstrate the utility of these variables in reconstructing the nature of biological interactions among populations (Howells, 1973, 1989). Because all samples included in this study derive from sedentary, agricultural communities and from sites that differ little in latitude, a comparison of craniometric variation among these samples should suffer no systemic biases due to differences in masticatory stresses or natural selection for dramatically different environments.

MATERIALS AND METHODS

Materials

Bronze Age skeletal samples from Central Asia, Iran, and the Indus Valley are relatively few in number and often recovered in fragmentary condition (Fig. 1). Nevertheless, 11 samples, numbering 525 individuals (270 males, 255 females) are compared to assess patterns of biological affinity within and across these regions of the Indo-Iranian borderlands (Table 1). An additional sample from Anatolia, Tell al-Judiadah, is included as an outgroup to provide a context for the degree and patterning of craniometric variation. Fourteen cranial variables (six for the neurocranium and eight for the facial skeleton) of those defined by Martin (1928) provide the metrical basis for the current study (Table 2).

The samples included in this analysis largely date to Bronze Age contexts from Central Asia, the Indus Valley, Iran, and

TABLE 2. Craniometric variables used to generate Mahalanobis generalized distances (d^2) between samples

	Variable ¹
Neurocranium	
Maximum cranial length (GOL)	1
Maximum cranial breadth (BEB)	8
Auricular height (AVH)	21
Sagittal arc (SAA)	25
Horizontal circumference (CAB)	23b
Minimum frontal breadth (BFTB)	9
Facial skeleton	
Upper facial height (NPH)	48
Nasal height (NH)	55
Nasal breadth (NB)	54
Orbital height (OH)	52
Orbital breadth (OB)	51a
Bizygomatic breadth (BZB)	45
Internal palatal length (IPL)	62
Internal palatal breadth (IPB)	63

¹ Numbers of the variables as defined by Martin (1928).

Anatolia. For those samples obtained from mixed periods (Tell al-Judiadah, Timargarha), the majority of individuals are of Bronze Age antiquity. All samples, except for the sample from Tell al-Judiadah, span a relatively narrow time frame between 3500 and 800 B.C.

The site of Sapalli tepe represents the most thoroughly documented Oxus Civilization settlement in the north Bactrian oasis (Askarov, 1974, 1977). All human remains recovered from Sapalli tepe have been assigned to the Sapalli phase of the Oxus Civilization. A single radiocarbon date (2009 B.C.; Hiebert, 1994) suggests a time span for the Sapalli phase between 2200 and 2000 B.C. The Sapalli tepe sample includes 39 adult individuals with cranial remains (13 males, 26 females). All craniometric measurements for the Sapalli tepe skeletal series were made by the author at the Institute of Archaeology, Uzbek Academy of Sciences, Samarkand, Uzbekistan.

Excavations of the Bronze Age site of Djarkutan in the north Bactrian oasis by the Institute of Archaeology, Uzbek Academy of Sciences, under the direction of Askarov (Askarov and Abdullaev, 1983) and Sirinov (Askarov and Sirinov, 1991) led to the discovery of a large cemetery south of the habitation area. Partial excavation of the cemetery resulted in recovery of 113 adult individuals (46 males, 67 females) with cranial remains. The human remains recovered from Djarku-

tan have been assigned to three successive chronological phases defined by Abdullaev (1979): the Djarkutan (DJR) phase (2000–1800 B.C.), the Kuzali (KUZ) phase (1800–1650 B.C.), and the Molali (MOL) phase (1650–1500 B.C.). All measurements for these remains were made by the author at the Institute of Archaeology, Uzbek Academy of Sciences, Samarkand, Uzbekistan.

Abbreviations, sample sizes, and sample locations for comparative samples are provided in Table 1 and Figure 1. The degree of interobserver error was assessed by means of repeated measures analysis of variance (Hemphill et al., 1991; Hemphill, in press) and indicated no significant measurement differences between observers for individuals obtained from Tepe Hissar, Tell al-Judiadah, the Bactrian samples, and Harappa (Cemetery R37, Cemetery H). Interobserver error could not be assessed for samples obtained from Shahr-I Sokhta or Mohenjo-daro.

Methods

The covariance matrix for each sample is obtained for males and females pooled together with list-wise deletion. Although pairwise deletion permits greater effective sample sizes within each sample, listwise deletion is used to avoid systematic biases caused by overrepresentation and underrepresentation of individual variables (Wilkinson, 1990). A pooled covariance matrix is obtained for all samples and bias-adjusted to accommodate differences in sample size. Variable averages are calculated for both males and females. Sex-standardized group values for each variable are obtained by taking the average of male and female mean values for each sample (Table 3). The bias-adjusted pooled covariance matrix and sex-standardized group values are used to obtain Mahalanobis generalized distances (d^2) between each pair of samples. The diagonal matrix of Mahalanobis d^2 values are provided in Table 4.

The diagonal matrix of Mahalanobis d^2 values is used as input for cluster analyses. Different associating algorithms are used to provide two perspectives on the patterning of intersample phenetic affinities. These associating algorithms include the weighted pair-group arithmetic average linkage method

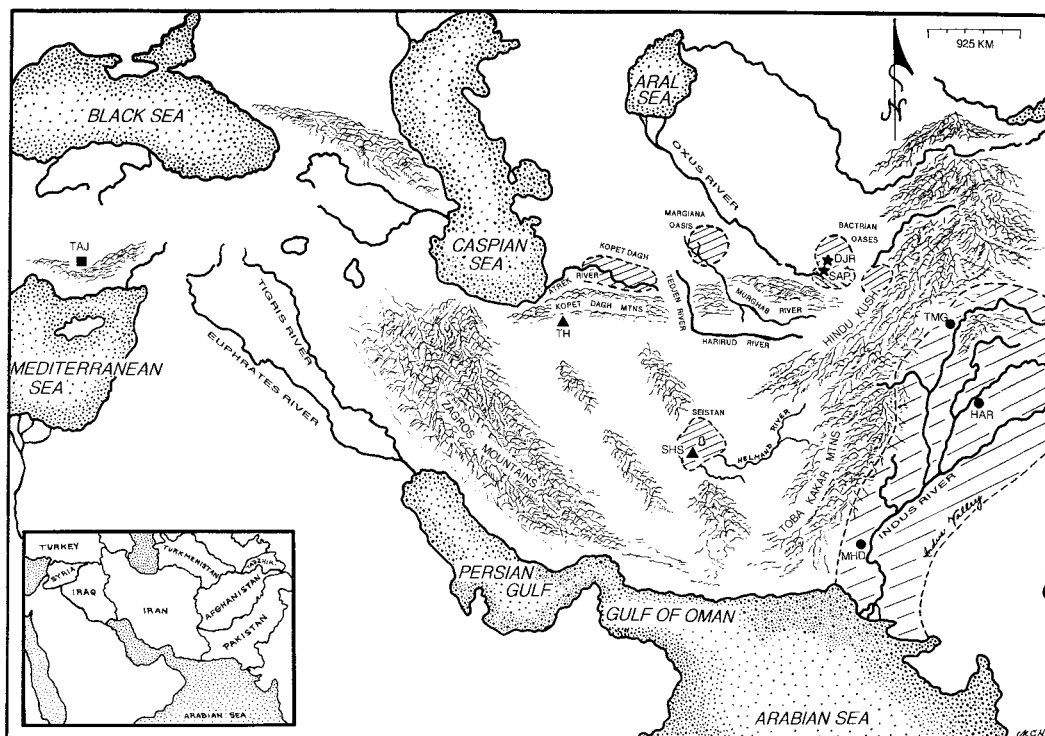


Fig. 1. Geographic location of Bronze Age craniometric samples. Oxus Civilization samples are represented by stars, Iranian samples by triangles, Indus Valley samples by circles, and Tell al-Judiadah by a square. Abbreviations for samples are defined in the text.

(WPGMA) (Sneath and Sokol, 1973) and the neighbor-joining method (Saitou and Nei, 1987; Felsenstein, 1989). The cophenetic correlation coefficient, r_{cs} (Sneath and Sokol, 1973), is computed with the NTSYS-pc statistical package to measure the degree of correspondence between the obtained phenogram from WPGMA cluster analysis and the original resemblance matrix.

The diagonal matrix of Mahalanobis d^2 values is used as input for nonmetric multidimensional scaling to provide a third perspective on the patterning of intersample affinities. Kruskal's stress formula number one (Kruskal, 1964a,b) is used to calculate distances between individual points. The goodness of fit obtained by multidimensional scaling is assessed by calculating of the degree of stress obtained through 100 iterations. Multidimensional scaling is accomplished with the SYSTAT statistical package (Wilkinson, 1990). Results obtained are ordinated in three-dimensional space,

and a minimum spanning tree (Hartigan, 1975) is imposed on the array of data points to ease interpretation of intersample associations.

Principal coordinates analysis is used to provide a fourth perspective on intersample craniometric variation. Principal coordinates analysis is preferred over principal components analysis in situations in which the number of variables exceeds the number of samples compared (Hair et al., 1971). The symmetric matrix of Mahalanobis d^2 values is double-centered before entry into NTSYS-pc statistical software. The first three principal coordinate axes are retained; group scores are calculated along these axes and ordinated into three-dimensional space. As with results from multidimensional scaling, a minimum spanning tree is imposed on the array of principal coordinate scores to ease interpretation of intersample associations. The cophenetic correlation coefficient is computed to assess the goodness of fit of the

TABLE 3. Mean values of craniometric variables

Variables:	GOL ¹	BEB	AVH	SAA	CAB	BFTB	NPH	NH	NB	OH	OB	BZB	IPL	IPB
Male sample ²														
CEMH	188.2	141.3	118.2	376.3	533.0	96.3	67.9	50.8	26.3	32.9	41.3	134.8	45.7	39.5
DJR	186.9	134.7	115.1	374.0	514.4	94.6	69.9	50.7	24.8	30.9	37.5	131.3	45.1	39.5
HAR	187.3	134.5	115.2	376.5	521.6	95.8	69.2	51.4	26.5	33.2	41.4	131.5	49.1	38.9
KUZ	190.9	138.9	120.3	386.7	534.3	96.0	68.7	49.6	26.4	30.9	39.9	134.0	44.3	40.0
MHD	188.0	132.5	119.9	386.2	518.5	93.6	71.1	49.1	24.2	32.9	39.1	127.8	52.4	42.8
MOL	185.6	138.1	115.3	377.4	514.7	95.0	69.4	51.5	25.1	31.8	38.3	126.6	44.2	39.7
SAP	183.5	134.9	112.3	370.9	506.7	93.0	70.2	51.3	24.2	32.7	37.7	129.1	43.1	38.6
SHS	185.8	136.4	120.2	377.0	511.9	96.0	70.2	50.6	25.7	31.8	42.1	129.4	47.0	40.1
TAJ	178.0	142.9	115.7	366.3	511.7	96.9	67.1	52.5	24.8	33.4	41.2	133.7	44.1	39.5
TH2	188.8	132.0	116.2	374.4	515.9	94.2	70.3	50.4	25.1	31.6	41.0	125.3	46.8	40.7
TH3	188.4	134.1	115.4	379.3	515.6	95.5	69.8	50.6	25.4	32.1	41.2	127.3	47.6	40.1
TMG	190.2	132.0	117.7	381.2	521.4	93.8	70.3	50.0	22.9	33.3	41.5	133.0	48.3	39.8
Female sample														
CEMH	179.2	132.4	108.6	363.6	500.8	92.5	62.7	46.0	24.4	33.3	39.9	119.5	44.2	35.1
DJR	184.7	134.0	113.2	376.9	511.3	93.8	69.5	50.2	25.6	33.0	38.5	123.9	42.5	39.5
HAR	180.9	132.1	110.6	371.9	506.1	93.2	66.2	48.3	24.2	34.1	40.6	123.9	45.1	36.4
KUZ	179.3	132.6	112.5	373.5	506.3	91.5	65.1	46.8	23.6	30.7	36.3	122.4	42.5	37.6
MHD	179.2	119.9	115.6	366.2	466.8	86.7	60.4	46.4	22.2	33.6	37.7	105.8	40.5	34.5
MOL	183.5	134.2	112.7	373.3	506.6	93.6	70.6	49.7	25.0	32.6	38.8	126.5	44.4	37.9
SAP	181.5	134.1	111.7	361.3	505.4	92.5	67.5	49.2	24.8	33.0	37.2	124.4	43.2	36.3
SHS	179.1	133.3	116.0	367.7	499.2	93.9	67.6	50.0	24.5	31.9	40.7	122.7	45.7	38.2
TAJ	164.9	141.2	109.2	351.2	487.5	93.9	59.3	45.0	21.8	32.4	36.4	124.0	40.5	36.6
TH2	178.3	132.1	113.6	366.9	499.9	91.7	67.6	48.3	23.7	33.6	38.7	118.7	46.3	37.6
TH3	179.4	131.8	111.3	365.9	498.2	92.2	66.1	48.3	23.9	31.7	39.6	120.2	45.5	38.2
TMG	180.2	130.9	114.7	363.8	501.7	91.7	66.6	48.1	22.9	33.1	40.0	122.3	41.5	37.0
Sex-standardized sample														
CEMH	183.7	136.8	113.4	370.0	516.5	94.4	65.3	48.4	25.3	33.1	40.6	127.1	44.9	37.3
DJR	185.8	134.3	114.2	375.4	512.9	94.2	69.7	50.5	25.2	32.0	38.0	127.6	43.8	39.5
HAR	184.1	133.3	112.9	374.2	513.8	94.5	67.7	49.9	25.4	33.6	41.0	127.7	47.1	37.6
KUZ	185.1	135.7	116.4	380.1	520.3	93.8	66.9	48.2	25.0	30.8	38.1	128.2	43.4	38.8
MHD	183.6	126.2	117.7	376.2	492.6	90.2	65.8	47.8	23.2	33.2	38.4	116.7	46.4	38.6
MOL	184.5	136.1	114.0	375.3	510.7	94.3	70.0	50.6	25.1	32.2	38.6	126.5	44.3	38.8
SAP	182.5	134.5	112.0	366.1	506.1	92.7	68.8	50.2	24.5	32.9	37.5	126.7	43.1	37.5
SHS	182.5	134.8	118.1	372.3	505.5	94.9	68.9	50.3	25.1	31.8	41.4	126.0	43.3	39.1
TAJ	171.4	142.0	112.5	358.8	499.6	95.4	63.2	48.8	23.3	32.9	38.8	128.8	42.3	38.1
TH2	183.5	132.1	114.9	370.7	507.9	93.0	69.0	49.4	24.4	32.6	39.9	122.0	46.5	39.1
TH3	183.9	133.0	113.4	372.6	506.9	93.9	69.9	49.4	24.7	31.9	40.4	123.8	46.5	39.1
TMG	185.2	131.5	116.2	372.5	511.6	92.7	68.4	49.1	22.9	33.2	40.8	127.7	44.9	38.4

¹ Abbreviations for craniometric variables are from Table 2.² Abbreviations for samples are defined in the text.TABLE 4. Matrix of Mahalanobis d^2 generalized distances

	CEMH ¹	DJR	HAR	KUZ	MHD	MOL	SAP	SHS	TAJ	TH2	TH3	TMG
CEMH	0											
DJR	6.265	0										
HAR	2.328	5.860	0									
KUZ	5.618	3.685	7.509	0								
MHD	18.702	13.953	15.019	20.815	0							
MOL	6.546	0.822	5.446	6.262	12.768	0						
SAP	5.215	1.305	5.212	5.703	15.802	1.551	0					
SHS	8.252	6.782	6.932	11.552	8.365	5.018	8.532	0				
TAJ	9.471	11.306	10.391	14.533	26.188	9.302	8.804	11.884	0			
TH2	5.393	4.522	4.836	7.862	7.554	4.069	5.969	2.616	13.929	0		
TH3	5.678	3.714	3.933	8.715	8.472	2.370	5.047	1.878	11.052	1.321	0	
TMG	5.106	6.243	4.842	5.906	11.162	7.291	6.197	7.069	14.362	4.480	5.653	0

¹ Abbreviations are defined in the text.

obtained eigenvectors with the matrix of Mahalanobis d^2 values. This latter step is especially important because the cophenetic correlation coefficient provides more informa-

tion on the *patterning* of relative phenetic distances among samples than the *absolute distance* (as indicated by the percentage of total variation explained by the first three

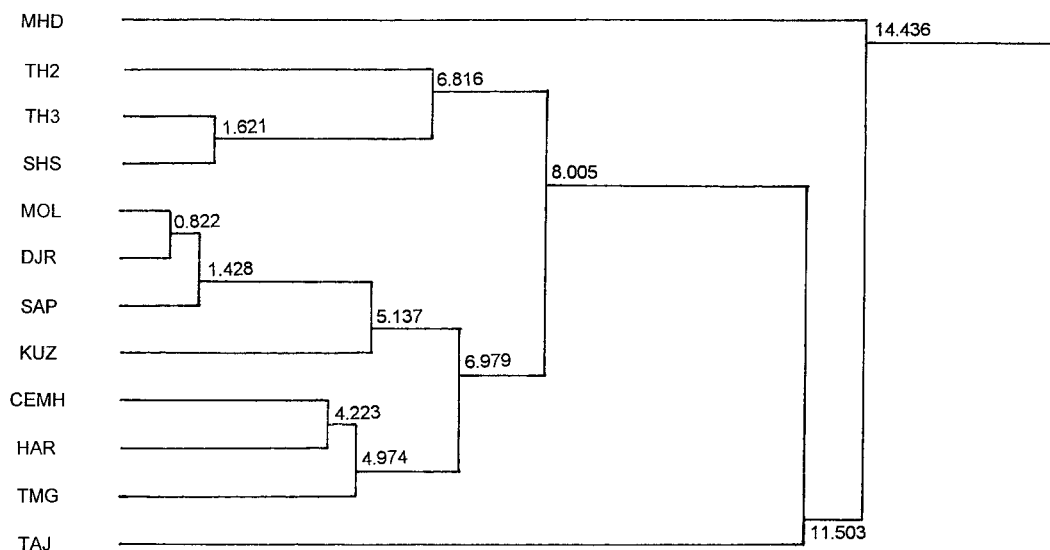


Fig. 2. WPGMA cluster analysis of Mahalanobis d^2 values. Branch points are euclidean distances. Abbreviations for samples are defined in the text.

eigenvectors) (Rolf, 1972, 1994), and it is the patterning of these relative distances that is most useful for understanding processes of past population interactions.

As a final step in assessment of the nature of intersample craniometric variation, spatial distance and temporal distance matrices are computed among all sample pairs. Congruence between the Mahalanobis d^2 matrix and these latter two matrices are assessed by means of the Mantel test (Mantel, 1967) and Mantel correlation coefficient (Smouse et al., 1986). These statistics test whether differences between samples may simply be attributed to geographical propinquity or differences in antiquity. Significance of these associations is obtained through 1,000 permutations at random by rows and columns.

RESULTS

The bias-adjusted matrix of Mahalanobis d^2 values (Table 4) was calculated according to the procedures outlined above. The vast majority of d^2 values between samples are significant (61 of 66; 92.4%). Of the 61 pairwise contrasts exhibiting a significant difference, 6 (9.8%) are significant at the 0.05 level, and 55 (90.2%) are significant at the 0.01 level. An examination of this matrix reveals that two samples, Mohenjo-daro

(MHD) and Tell al-Judiadah (TAJ), stand out as distinct outliers by exhibiting very large Mahalanobis distances from all other samples.

WPGMA cluster analysis

The dendrogram obtained by means of the WPGMA associating algorithm (Fig. 2) confirms the outlier status of TAJ and MHD. Remaining samples are arranged in three distinct groups, and these groups may be identified as Iranian samples, north Bactrian samples, and samples from the Indus Valley. Within the group of samples from Iran, affinities between Shahr-i Sokhta (SHS) and Tepe Hissar 3 (TH3) appear relatively close, whereas the earlier inhabitants of Tepe Hissar (TH2) join these two samples at a more distant remove. Among north Bactrians, affinities are closest between MOL and DJR phase inhabitants of Djarkutan, with the earlier Sapalli phase (SAP) sample from Sapalli tepe somewhat more distant. The KUZ phase sample exhibits a distant association to all other north Bactrians. Indus Valley samples, except for the highly divergent individuals from Mohenjo-daro, exhibit diffuse associations but are more similar to one another than to Iranians or north Bactrians. Affinities are slightly closer

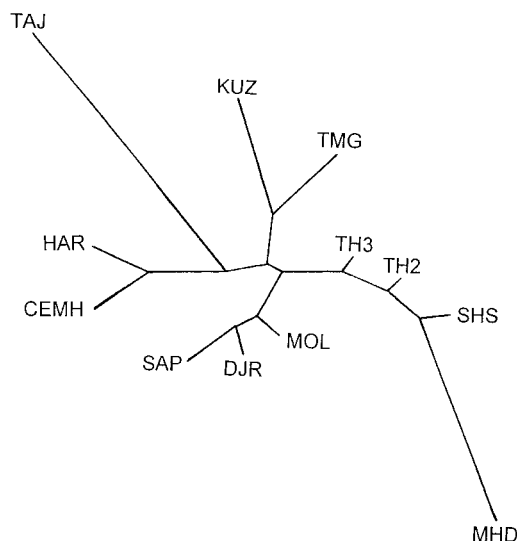


Fig. 3. Neighbor-joining tree based on Mahalanobis d^2 values. Abbreviations for samples are defined in the text.

between mature phase Cemetery R37 (HAR) and late-Harappan Cemetery H (CEMH) individuals than with the post-Harappan sample from Timargarha (TMG). Overall, north Bactrians exhibit slightly closer associations with Indus Valley inhabitants than with Iranians.

Neighbor-joining cluster analysis

Neighbor-joining cluster analysis (Fig. 3) provides a different cluster representation of the distance matrix than that provided by WPGMA cluster analysis, because it is an unrooted tree whose branches have different lengths. Long branch lengths may be interpreted as an indicator of a large degree of phenetic separation, whereas short branch lengths are indicative of a small degree of phenetic separation between samples. The neighbor-joining tree provides an array of sample distances largely in agreement with those depicted by WPGMA (Fig. 2). TAJ and MHD are again identified as distant outliers to all other samples by their locations in the extreme upper left and extreme lower right of this array. The three geographical groupings of samples identified by WPGMA cluster analysis are also largely confirmed. Two of the Indus Valley samples, HAR and CEMH, exhibit closest affinities to one another. Three of the north Bactrian samples (SAP, DJR, MOL) exhibit closest affinities to one another, and the three Iranian samples (TH3, TH2, SHS) are grouped together in the middle-right of this array.

Nevertheless, four important differences may be identified. First, the peripheral members of Indus Valley samples (TMG) and north Bactrian samples (KUZ) exhibit closer associations to one another, albeit diffuse, than to other samples from their respective regions. Second, associations between the three remaining north Bactrian samples (SAP, DJR, MOL) are slightly closer to Iranians than to the two Indus Valley samples from Harappa (HAR, CEMH). Third, affinities among Iranians are closer between the two samples from Tepe Hissar (TH2, TH3) than with the sample from eastern Iran (SHS). Fourth, north Bactrians (except for the highly divergent KUZ phase sample) are arranged in reverse chronological order from the main line of intersample variation. That is, the earliest sample, SAP, is most divergent, followed by the temporally successive DJR phase sample; the chronologically most recent sample, MOL, is least differentiated from the main line of intersample variation.

Cophenetic correlation coefficients

The cophenetic correlation coefficient for the degree of correspondence between the phenogram obtained by WPGMA cluster analysis and the bias-adjusted matrix of Mahalanobis d^2 values is somewhat low ($r_{cs} = 0.678$). This suggests that a fair amount of distortion is encountered when attempting to arrange intersample differences in craniometric variation in a hierarchical fashion through cluster analysis (Rolf, 1994).

Sneath and Sokol (1973) recommend that alternative methods of data reduction be used in such cases where cophenetic correlations indicate that a fair amount of distortion of the original data matrix is incurred by hierarchical cluster analyses. Specifically, they recommend use of multidimensional scaling and principal coordinates analysis to provide a more robust representation of intersample affinities.

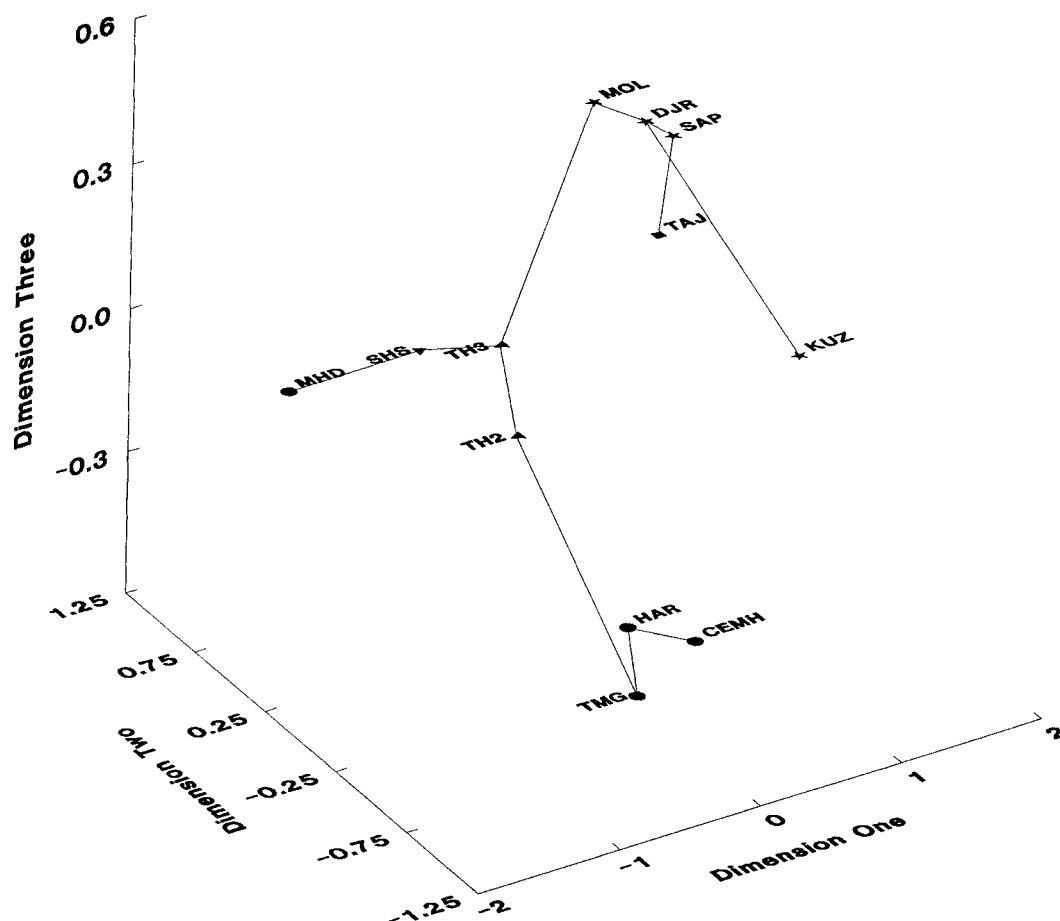


Fig. 4. Minimally spanned plot of sample values for the first three multidimensionally scaled dimensions. Sample symbols are the same as in Figure 1. Abbreviations for samples are defined in the text.

Multidimensional scaling

Multidimensional scaling of the bias-adjusted diagonal matrix of Mahalanobis d^2 values into three dimensions with Kruskal's formula one is accomplished with a stress value of 0.026 after 100 iterations. This value falls well within acceptable limits (Kruskal, 1964a,b) and indicates that multidimensional scaling of these data into three dimensions provides an array of inter-sample associations little affected by distortion (Sneath and Sokol, 1973). A plot of multidimensionally scaled values with a minimum spanning tree imposed between individual data points is provided in Figure 4.

An examination of this array confirms the three regional groups identified by WPGMA cluster analysis (Fig. 2). Indus Valley samples all occur in the lower left of the array and exhibit closer associations with one another than to any others included in this analysis. The minimum spanning tree indicates that connections between Indus Valley and other regional samples are closest between TMG and the earlier sample from TH2, but this connection is not close. North Bactrian samples occupy the upper right of this array. As indicated by both WPGMA and neighbor-joining cluster analyses, associations between SAP, MOL, and DJR are close, whereas the KUZ phase

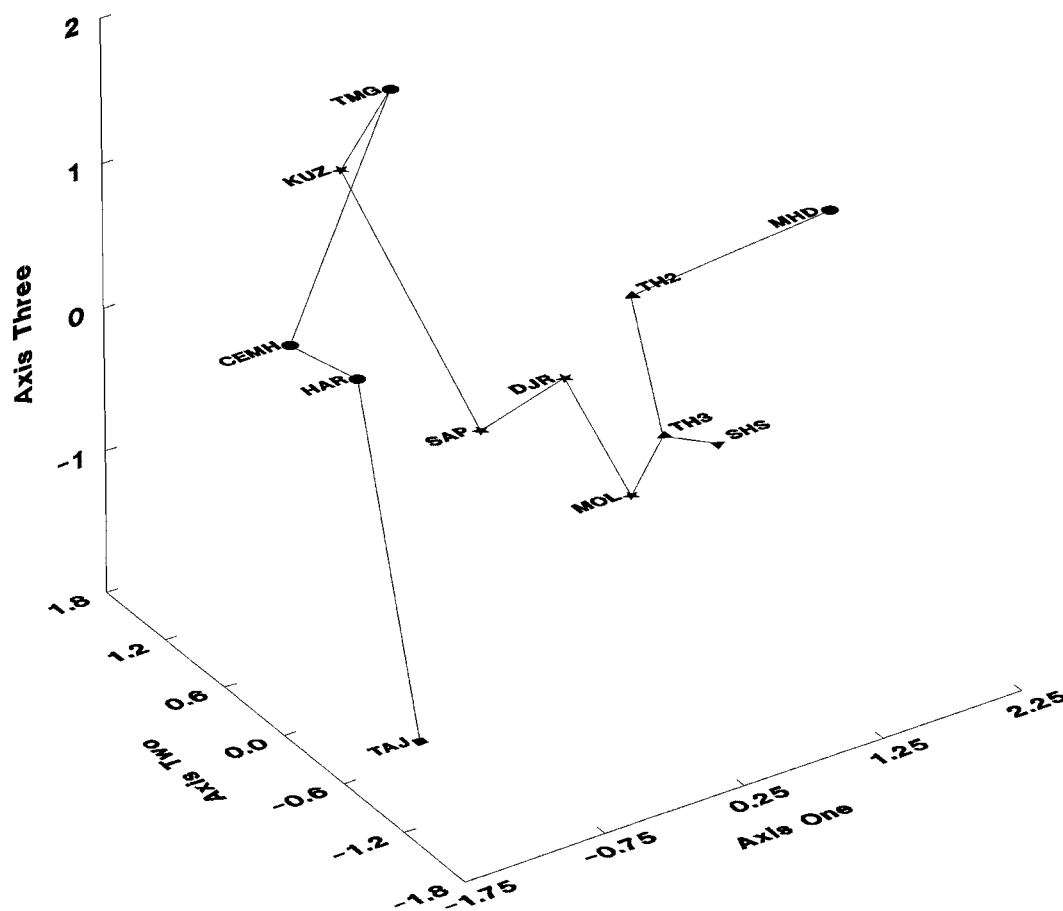


Fig. 5. Minimally spanned ordination of sample scores for the first three principal coordinate axes. Sample symbols are the same as in Figure 1. Abbreviations for samples are defined in the text.

sample is markedly divergent. The minimum spanning tree indicates that connections between north Bactrians and other regional samples are closest between the most recent of the north Bactrians, MOL, and the later sample from TH3. Again, as for interregional associations of Indus Valley samples, connections between north Bactrians and other regional samples are not close. Iranian samples (TH2, TH3, SHS) occupy the center of this ordination and exhibit closer affinities to one another than to those from other regions. In agreement with WPGMA cluster analysis, this array indicates that the later Tepe Hissar sample (TH3) possesses slightly closer affinities to eastern Iranians from SHS than to the earlier sample from TH2. Both MHD and

TAJ represent distinct outliers to all other samples, but the distinctiveness of this separation is not as explicit as in the arrays provided by cluster analyses.

A principal coordinates analysis of the double-centered Mahalanobis d^2 matrix yields three coordinate axes that combine to explain 91.8% of the total variance. Comparison of the eigenvector matrix with the Mahalanobis d^2 matrix yields a cophenetic correlation coefficient value ($r_{cs} = 0.952$) which indicates that the first three eigenvectors provide an excellent fit of the data (Rolf, 1994). An ordination of group scores for the first three coordinate axes is provided in Figure 5. A minimum spanning tree is imposed on this array to clarify associations between samples. TAJ and MHD occupy

isolated positions in the extreme left and right sides of this array, respectively, thus reaffirming their outlier status relative to all other samples. The three regional aggregations of samples are also confirmed. Indus Valley samples occupy the upper left of this array. As indicated by WPGMA and neighbor-joining cluster analyses, affinities are closest between CEMH and HAR individuals, whereas post-Harappan individuals from TMG are more distantly removed. North Bactrian samples occupy the center of the ordination. As indicated by all other analyses, associations between SAP, DJR, and MOL phase samples are relatively close, whereas the KUZ phase sample features only a distant association with other north Bactrians. In agreement with neighbor-joining analysis but in contrast to multidimensional scaling, ordination of principal coordinate scores suggests a connection between Indus Valley and north Bactrian oasis inhabitants, through a moderate association between TMG and KUZ samples. Iranians occupy the center right of Figure 5. The patterning of associations among Iranian samples confirms the closer affinities between the later inhabitants of TH3 and SHS identified by WPGMA cluster analysis (Fig. 2). Principal coordinates analysis also verifies the reverse chronological patterning of affinities between north Bactrian (except KUZ phase) and Iranian samples through TH3, indicated by both neighbor-joining cluster analysis and multidimensional scaling.

Mantel tests

The Normalized Mantel statistic, which is equivalent to a correlation coefficient (r), obtained between the Mahalanobis d^2 matrix and the matrix of chronological differences between samples is -0.032 . The permutational probability to observe a higher or equal correlation based on 1,000 permutations is $P = 0.497$. This value suggests that differences in antiquity provide little explanation of the patterning of craniometric differentiation among these Bronze Age samples. By contrast, a comparison between the Mahalanobis d^2 matrix and the matrix of geographical distances between samples yields a correlation coefficient of $r = 0.464$. The permutational probability to observe a

higher or equal correlation is nearly significant, with a value of $P = 0.055$. This suggests that the amount of geographic distance between individual samples represents an important, but by no means exclusive, contributing factor behind the patterning of craniometric differentiation among these Bronze Age samples.

DISCUSSION

Origins of the Oxus Civilization

Three hypotheses have been advanced to account for the appearance of the Oxus Civilization within the oases of Central Asia during the final centuries of the third millennium B.C. The first holds that Oxus Civilization oases populations owe their ultimate origins to populations of the Gorgan Plain in northern Iran. These Iranian populations spread northeastward from the Gorgan Plain to the Kopet Dagħ foothill plain of Turkmenistan during the fourth millennium B.C., and then moved eastward into the oases of Margiana and Bactria immediately before the rise of the Oxus Civilization (*c.* 2200 B.C.). Proponents of this hypothesis assert that immigration from the urban centers of the Kopet Dagħ foothill plain was predicated upon a refinement in irrigation technology that not only led to population pressure in the Kopet Dagħ, but also made possible a wholesale colonization of the previously unoccupied oases of Bactria and Margiana.

If this hypothesis is true, we expect north Bactrians to possess closest affinities to the northern Iranian samples from Tepe Hissar. More specifically, if the initial occupation of the north Bactrian oasis was one of wholesale colonization, we expect affinities between north Bactrians and northern Iranians to be especially close between the early sample from TH2, which is contemporaneous with proposed initial emigration to the Kopet Dagħ foothill plain during the fourth millennium B.C., and the earliest of the north Bactrian samples, SAP.

Results from this analysis provide little support for this hypothesis. Although the array of affinities provided by neighbor-joining analysis, multidimensional scaling, and principal coordinates analysis indicate that north Bactrians exhibit closer affinities to northern Iranians than to any other non-

Central Asians, these affinities are not of the immediate proximity expected from wholesale colonization. In addition, affinities are not closest between the earliest north Bactrian sample (SAP) and the earlier sample from TH2. Rather, closest affinities occur with the latest of the north Bactrian samples, MOL, and the more recent northern Iranian sample from TH3. Thus, although it is possible that Oxus Civilization populations may have their ultimate origins among earlier northern Iranian populations, the initial peopling of the north Bactrian oasis before the rise of the Oxus Civilization appears more complex than a simple wholesale transplantation of northern Iranian-affiliated populations from the urban centers of the Kopet Dagh foothill plain into previously unoccupied oases.

The second hypothesis also calls for the ultimate origins of north Bactrian populations from northern Iran via the Kopet Dagh foothill plain, but differs by asserting that the oases of Margiana and Bactria were inhabited before the appearance of the Oxus Civilization. This model suggests that the impact of immigrating populations from the urban centers of the Kopet Dagh foothill plain on the populations of Margiana and Bactria was one of steady, unidirectional gene flow into a preexisting resident population.

If this hypothesis is valid, north Bactrian samples should exhibit closest affinities to northern Iranian populations. However, because the proposed relationship between these two regions was one of low-level, unidirectional gene flow from west to east, affinities may not be exceptionally close. In addition, if this gene flow continued in a unidirectional manner from west to east, later north Bactrian samples should exhibit closer affinities to northern Iranians than earlier north Bactrian samples, who may not have experienced substantial gene flow from populations of the Kopet Dagh foothill plain.

Results from this analysis provide marginal support for this hypothesis. The array of affinities identified by neighbor-joining analysis, multidimensional scaling, and principal coordinates analysis confirms that of all non-Central Asian samples, northern Ira-

nians bear closest phenetic affinities to north Bactrians and that these affinities are not especially close. In addition, these analyses also indicate that, apart from the highly divergent KUZ phase sample, north Bactrian samples are arranged in reverse chronological order with respect to the degree of affinity to northern Iranians. This pattern is consistent with a model that calls for long-standing, low-level, unidirectional gene flow between northern Iranian-affiliated Kopet Dagh populations and the inhabitants of the north Bactrian oasis.

The third hypothesis suggests that Oxus Civilization populations of the north Bactrian oasis, and perhaps Margiana, may owe their ultimate origins to Harappan populations of the Indus Valley, rather than to northern Iranian-affiliated Kopet Dagh foothill plain populations. If true, we expect north Bactrians to exhibit closest affinities with Indus Valley samples and more distant affinities with northern (TH2, TH3) and eastern Iranians (SHS).

The results provided by this analysis offer no support for this hypothesis. Although WPGMA cluster analysis indicates slightly closer affinities between north Bactrians and Indus Valley inhabitants, these affinities are not confirmed by any other analyses. Quite the contrary, apart from indications of a distant association between the highly divergent KUZ phase sample and the post-Harappan sample from TMG, all other analyses consistently indicate that Indus Valley inhabitants are phenetically more distant from north Bactrians than northern and eastern Iranians. Hence, this analysis corroborates results obtained in an earlier study of dental morphology (Hemphill et al., 1997, *in press*) in finding no support for any model that calls for the ultimate origins of north Bactrian oasis Oxus Civilization populations to be inhabitants of the Indus Valley.

Taken together, the results of this analysis do not provide any evidence to indicate that Oxus Civilization populations of the north Bactrian oasis are the product of a wholesale colonization by northern Iranian-affiliated populations from the urban centers of the Kopet Dagh foothill plain. Nor do they support a model that calls for the ultimate origin of these oasis populations to

be inhabitants of the Indus Valley. The results are more consistent with interaction that involved low-level, unidirectional gene flow from the urban centers of the Kopet Dagh foothill plain into extant resident populations of Bactria and Margiana. Nevertheless, even this model is inadequate to fully explain the origins of the Oxus Civilization populations of north Bactria.

First, closest affinities between later north Bactrians (DJR, KUZ, MOL) and northern Iranians do not occur with the earlier sample from TH2 as expected if the populations of the urban centers of the Kopet Dagh foothill plain stem from a migration of northern Iranian populations during the fourth millennium B.C. Rather, the affinities that do exist between later north Bactrians and northern Iranians are with the later Tepe Hissar sample (TH3). This suggests that gene flow continued from west to east long after the urban centers of the Kopet Dagh foothill plain declined (Masson and Sarianidi, 1972; Masson, 1992a,b) or atomized into small villages (Biscione, 1977) around 2200 B.C.

Second, if the Oxus Civilization inhabitants of the north Bactrian oasis are the product of a resident oasis population that experienced long-standing, low-level unidirectional gene flow from northern-Iranian affiliated Kopet Dagh populations, later north Bactrian populations should reflect the cumulative effect of this gene flow by exhibiting ever-closer affinities to the two samples from Tepe Hissar. Although this pattern holds true for DJR and MOL phase north Bactrians, KUZ phase individuals represent a glaring departure. If the statistical placement of KUZ phase north Bactrians is not the product of sampling error, these unique phenetic affinities may support Hiebert's (personal communication, 1997) suggestion that Kuzali ceramic wares are more properly interpreted as signaling the presence of a separate social or ethnic group at Djarkutan, rather than reflecting a distinct chronological phase of occupation of this site.

Interregional effects of the Oxus Civilization

Three hypotheses have been offered for the interregional effects of Oxus Civilization

populations on neighboring Bronze Age populations. These hypotheses emphasize that the Oxus Civilization represented the core of a new and vigorous commercial power whose influence spread during the later phases of this civilization throughout the Indo-Iranian borderlands during the first half of the second millennium B.C. However, these hypotheses differ dramatically over the nature of interactions between Oxus Civilization and neighboring Bronze Age populations. Proponents of the first two hypotheses believe that Oxus Civilization populations exerted a widespread, unidirectional effect on neighboring cultures but were themselves little affected by these cultures. Although most proponents of this unidirectional view limit their discussions to the movement of characteristic Central Asian artifacts rather than people, several scholars have specifically suggested a unidirectional movement of Oxus Civilization "conquerors" (Parpola, 1988) or "colonists" (Lamberg-Karlovsky, 1993; Hiebert, 1994) from the oases of Margiana and Bactria into Iran and the western border of Indus Valley during the initial centuries of the second millennium B.C.

If the rise of the Oxus Civilization in the oases of Central Asia actually led to a concentration of power in this region so that late-phase Oxus Civilization inhabitants conquered and replaced contemporaneous populations in the Indus Valley, we expect such an event to be reflected by the patterning of phenetic distances between north Bactrians and Indus Valley inhabitants. Specifically, the post-Harappan sample from Timargarha should be these north Bactrian "conquerors." Hence, Timargarha should exhibit a strong phenetic separation from earlier inhabitants of the Indus Valley (HAR, CEMH) and be virtually identical to late phase north Bactrians (KUZ, MOL).

The results provided in this analysis offer no support for the "conquerors" envisioned by Parpola. To be sure, one late north Bactrian sample (KUZ) does exhibit affinities to the single post-Harappan Indus Valley sample (TMG) included in this analysis. However, the nature of this affinity is inconsistent with Parpola's notions of population replacement, for the affinity between TMG and KUZ phase samples is extremely tenuous and inconsistent. A moderately close

affinity is identified by principal coordinates analysis, a distant association is depicted by neighbor-joining cluster analysis, and the three-dimensional ordination of multidimensionally scaled group scores fails to identify any affinity between these two samples. The conclusion to be drawn is that some association may exist between these two samples, but clearly this association is not of the immediate phenetic proximity expected under Parpola's model of "conquering armies" of north Bactrians replacing the indigenous post-Harappan populations of the Indus Valley.

If, however, the nature of interaction between Oxus Civilization and neighboring Bronze Age populations involved unidirectional colonization of these neighboring regions, gene flow from late phase north Bactrian "colonists" into the resident populations of post-Harappan Timargarha, and perhaps Tepe Hissar 3, should be reflected by these latter samples exhibiting closer affinities to north Bactrians than earlier Indus Valley (HAR, CEMH) and Iranian (TH2, SHS) samples. Because the nature of this interaction is held to be unidirectional—from the oases of Bactria and Margiana to neighboring areas—late phase north Bactrians (KUZ, MOL) should not exhibit a reduction of phenetic distance toward these other regional samples that draws them away from earlier north Bactrians (SAP, DJR).

This analysis provides no support for unidirectional colonization of Indus Valley or Iranian urban centers during the first half of the second millennium B.C. by Oxus Civilization populations. Whereas neighbor-joining cluster analysis, multidimensional scaling, and principal coordinates analysis offer some evidence of a reduction of phenetic distances between the latest samples from the Indus Valley (TMG), Iran (TH3), and north Bactrians, the nature of this reduction stands opposed to the expectations of this model. Quite simply, the reduction of phenetic distances is not unilateral. Rather, these analyses all depict the convergence between late-phase north Bactrians and Tepe Hissar 3 as involving an equal deflection of these samples away from earlier members of their respective regions. Comparisons between Indus Valley samples and north Bactrians stand at even greater odds with the

expectations of this model. The results either indicate an equal phenetic movement of late phase north Bactrians (KUZ) and post-Harappan Timargarha (principal coordinates analysis), a completely unique association between these samples (neighbor-joining analysis), or no convergence at all (multidimensional scaling).

The third hypothesis for the interregional effects of Oxus Civilization populations suggests that interactions among Central Asian, Indus Valley, and Iranian groups increased in intensity during the first half of the second millennium B.C. Jarrige (1994) argues that elites in these three regions participated in a bidirectional exchange network, or *koiné*. If the first half of the second millennium B.C. witnessed increased bidirectional exchange across the Indo-Iranian borderlands, such exchanges may have involved the movement of individuals (genes) and commodities. The effects of such exchanges should be reflected by the patterning of phenetic distances among Central Asian, Indus Valley, and Iranian samples. Specifically, earlier inhabitants of each of these respective regions should have experienced little interaction with inhabitants of other regions and therefore be marked by strong phenetic separations from one another. Later inhabitants, however, are expected to reflect the effects of this gene flow by exhibiting a reduction of the phenetic distances between them. Because this interaction is maintained to be bidirectional, late-phase inhabitants of the north Bactrian oasis (KUZ, MOL), the Indus Valley (TMG), and Iran (TH3) should manifest a general reduction of regional distinctiveness by moving *toward one another* to occupy a central phenetic position away from earlier inhabitants of each respective region.

This analysis provides greater support for bidirectional interaction across the Indo-Iranian borderlands during the first half of the second millennium B.C. than for models based on an assumption of unidirectional interaction. As expected, the array provided by neighbor-joining analysis places the latest north Bactrian (KUZ, MOL), Indus Valley (TMG), and Iranian (TH3) samples in more proximate positions to one another along the main line of intersample variation than earlier samples. A broadly similar pat-

tern is also revealed by multidimensional scaling, for ordination of the first three dimensions also reveals a slight degree of phenetic convergence among late-phase north Bactrians and Iranians through MOL and TH3. However, no reduction of phenetic distance occurs between late-phase north Bactrians and post-Harappan Indus Valley inhabitants. Ordination of the first three principal coordinate axes yields stronger evidence in support of bidirectional exchange than multidimensional scaling. As expected, affinities between north Bactrians and Indus Valley inhabitants occur among later samples (KUZ, TMG), and these latter samples occupy an intermediate position between earlier members of their respective regions. Likewise, affinities between north Bactrians and Iranians also occur among later samples (MOL, TH3); these samples also occupy a phenetic position intermediate between earlier members of their respective regions. However, in contrast to the expectations of the bidirectional model, the degree of phenetic convergence between late-phase Indus Valley and Iranian samples is not marked.

Hence, results obtained in this analysis offer no support for models that suggest that the interregional effects of Oxus Civilization populations on neighboring Bronze Age populations were unidirectional, regardless of whether the nature of this interaction was one that involved north Bactrian "conquerors" or "colonists." Rather, these results are more consistent with models that invoke a cultural *koiné* that involved bidirectional exchange across the Indo-Iranian borderlands. Nevertheless, two aspects of the patterning of affinities among late-phase samples suggests that even this model is incomplete.

First, there is no universal homogenization of phenetic differences across late-phase samples from north Bactria, the Indus Valley, and Iran. If such a general homogenization did occur, these samples should be most proximate to the main line of intersample variation in neighbor-joining analysis and occupy the center of arrays provided by multidimensional scaling and principal coordinates analysis. This is not the case. Rather, we see a bilateral reduction

of phenetic distances between post-Harappan Timargarha and Kuzali on one hand, and Molali and Tepe Hissar 3 on the other. Standing in direct opposition to Jarrige's model, there appears to be little, if any, phenetic reduction between late occupants of the Indus Valley (TMG) and Iran (TH3). A possible interpretation of these results is that Oxus Civilization populations served as "middlemen," mediating interactions between late-phase Indus Valley populations to the southeast and Iranian populations to the south and west. If true, these results confirm that the nature of interactions across the Indo-Iranian borderlands during the first half of the second millennium B.C. involved bidirectional exchange of individuals and commodities, but these exchanges (at least with respect to genes) appear more limited both in intensity and in geographic range than anticipated. By and large, samples from the north Bactrian oasis, the Indus Valley, and Iran remain regionally distinct from one another until the very end of the Bronze Age. This may explain why Mantel tests indicate that geographic propinquity accounts for an important, but by no means exclusive, contributing factor behind craniometric variation across these samples.

Second, two of the samples included in this analysis depart on a unique phenetic vector that cannot be attributed to any of the three regions included by Jarrige (1994) as participants a bidirectional *koiné* across the Indo-Iranian borderlands. Neighbor-joining analysis and principal coordinates analysis both indicate that Kuzali and Timargarha samples not only exhibit an association to one another, but also differ from earlier samples of their respective regions along a completely separate vector of variation. In neither case can the source of this departure be attributed to gene flow from Iranians. This suggests that if the cause of the unique phenetic deflection of Timargarha and Kuzali samples is the result of gene flow and not due to sampling error, the source of these genes must derive from some other population. The retention of strong interregional differences in cranial morphology until near the end of the Bronze Age, coupled with the potential influence of gene flow from a source outside the three regional populations (Oxus

Civilization, Indus Valley, Iran) included by Jarrige in the late Bronze Age *koiné* across the Indo-Iranian borderlands, may explain why Mantel tests indicate that temporal differences provide little explanation for the patterning of craniometric variation across these samples.

A possible source of gene flow that may account for the unique phenetic associations of Kuzali and Timargarha samples may be the Vakhsh/Beshkent cultures of southern Tajikistan and the southern Bactrian oasis of northeastern Afghanistan. Sites identified with Vakhsh/Beshkent cultures are contemporaneous with later phases of the Oxus Civilization and are located only 70 km to the south (Afghanistan) and to the east (Tajikistan) of Sapalli tepe. Vakhsh/Beshkent sites feature a unique fusion of late-phase Oxus Civilization ceramic wares coupled with burial practices and metal objects that bear closest affinities with steppe cultures of Kazakhstan to the north (Litvinsky, 1964, 1973, 1981; Mandel'shtam, 1966; Askarov, 1977; Litvinsky and P'yankova, 1992; P'yankova, 1993, 1994).

Interaction between Vakhsh/Beshkent and the Oxus Civilization populations are not only attested by the presence of Oxus Civilization style ceramics at Vakhsh/Beshkent sites, but also by recovery of a few Vakhsh/Beshkent material culture remains from Oxus Civilization urban centers (Askarov, 1977, 1981; P'yankova, 1993, 1994; Hiebert, 1994). In addition, Parpola (1994, 1995) has emphasized that Vakhsh/Beshkent cultures provide the most likely source for the appearance of the Gandharan Grave culture in such post-Harappan northern Indus Valley sites as Timargarha (see Dani 1966, 1967). Although intriguing, the hypothesis that the Vakhsh/Beshkent cultures provided a connection between late-phase Oxus Civilization populations and contemporary inhabitants of the Indus Valley cannot be tested until osteological data for inhabitants of these sites become available.

CONCLUSIONS

The results obtained in this analysis suggest that current hypotheses that seek to account for the origins and interregional effects of Oxus Civilization populations are

inadequate. The pattern of craniometric variation provides no support for models that suggest that Oxus Civilization inhabitants of the north Bactrian oasis owe their origins to transplanted northern Iranian-affiliated populations from urban centers of the Kopet Dagh foothill plain to the west or to Indus Valley populations from the southeast. The pattern of phenetic affinities exhibited by north Bactrians provides greater support for the hypothesis that these populations are the product of gene flow between northern Iranian-affiliated urban populations of the Kopet Dagh foothill plain and an extant population within the north Bactrian oasis. However, the close phenetic proximity between Molali phase inhabitants of the north Bactrian oasis and the later inhabitants of Tepe Hissar runs counter to this model and suggests that gene flow continued from west to east long after the urban centers of the Kopet Dagh foothill zone declined or atomized into smaller villages.

Analysis of the interregional effects of Oxus Civilization populations on neighboring Bronze Age populations provides no support for models that assume that the nature of this interaction was unidirectional. Although the results obtained are more consistent with a pattern of bidirectional exchange across the Indo-Iranian borderlands during the first half of the second millennium B.C., the intensity and geographic range of this interaction (at least with respect to gene flow) appears more limited than expected. In addition, the unique phenetic departure of Kuzali phase Bactrians and post-Harappan inhabitants of Timargarha suggests that a fourth population participated in this sphere of interaction during the late terminal Bronze Age. Currently, the best candidate for this role are populations of the Vakhsh/Beshkent cultures of southern Turkmenistan and northeastern Afghanistan. Unfortunately, the lack of osteological data for human remains attributed to the Vakhsh/Beshkent culture prohibits a definitive test of this possibility.

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